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FIG. 1

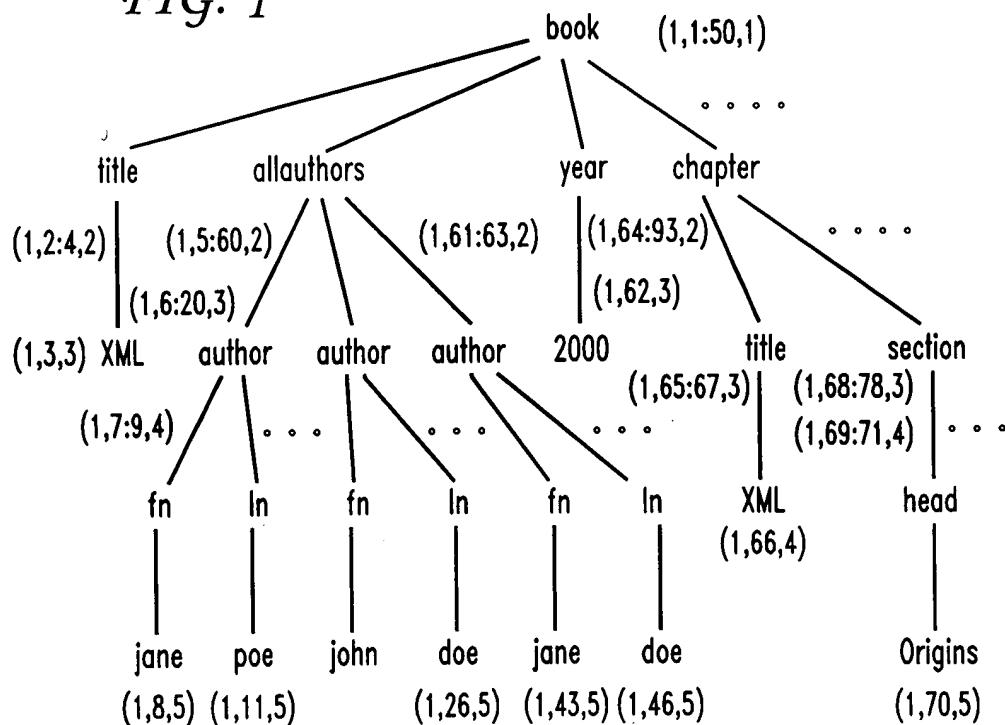


FIG. 2A

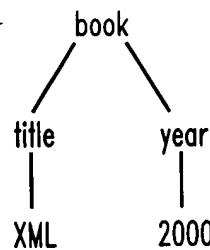
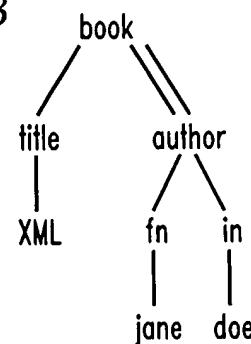


FIG. 2B



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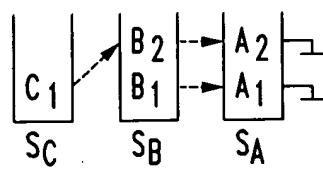
FIG. 3A

A₁
|
B₁
|
A₂
|
B₂
|
C₁
DATA

FIG. 3B

A
||
B
||
C
QUERY

FIG. 3C



STACK ENCODING

FIG. 3D

A₁ B₁ C₁
A₁ B₂ C₁
A₂ B₂ C₁
QUERY RESULTS

FIG. 4

```

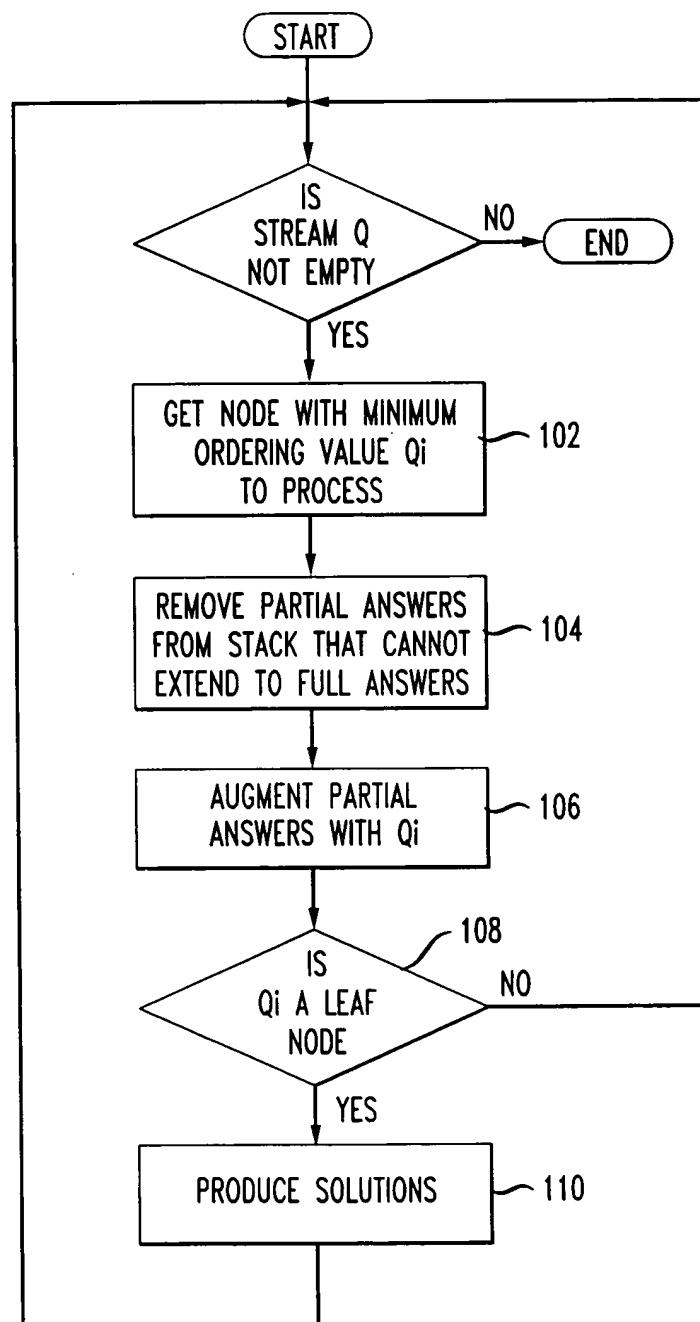
Algorithm PathStack(q)
01 while ¬end(q)
02   qmin = getMinSource(q)
03   for qi in subtreeNodes(q) // clean stacks
04     while (¬empty(Sqi) ∧ topB(Sqi) < nextL(Tqmin))
05       pop(Sqi)
06     moveStreamToStack(Tqmin, Sqmin, pointer to
                           top(Sparent(qmin)))
07   if (isleaf(qmin))
08     showSolutions(Sqmin,1)
09     pop (Sqmin)
Function end(q)
  return ∀qi ∈ subtreeNodes(q): isLeaf(qi) ⇒ eof(Tqi)
Function getMinSource(q)
  return qi ∈ subtreeNodes(q) such that nextL(Tqi)
  is minimal
Procedure moveStreamToStack(Tq,Sq,p)
01 push(Sq,(next(Tq),p))
02 advance(Tq)

```

PathStack

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FIG. 4A



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FIG. 5

```

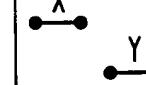
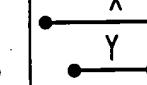
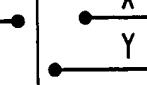
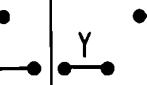
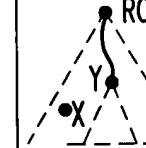
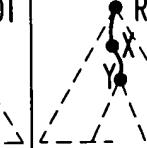
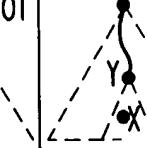
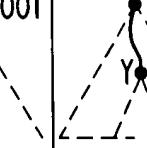
Procedure showSolutions(SN,SP)
// Assume, for simplicity, that the stack of the query
// nodes from the root to the current leaf node we
// are interested in can be accessed as S[1],...,S[n].
// Also assume that we have a global array index[1..n]
// of pointers to the stack elements.
// index[i] represents the position in the i'th stack that
// we are interested in for the current solution, where
// the bottom of each stack has position 1

// Mark we are interested in position SP of stack SN.
01 index[SN] = SP
02 if (SN == 1) // we are in the root
03 // output solutions from the stacks
04 output (S[n].index[n],...,S[1].index[1])
05 else // recursive call
06 for i = 1 to S[SN].index[SN].pointer_to_parent
07 showSolutions(SN - 1, i)

```

Procedure showSolutions

FIG. 6

	CASE 1	CASE 1	CASE 1	CASE 1
PROPERTY	X.R < Y.L X.R > Y.R	X.L < Y.L X.R < Y.R	X.L > Y.L X.R < Y.R	X.L > Y.R
SEGMENTS				
TREE				
CASES FOR PathStack AND TwigStack				

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FIG. 7

```
Algorithm PathMPMJ( $q$ )
01 while ( $\neg \text{eof}(T_q) \wedge (\text{isRoot}(q) \vee$ 
          $\text{nextL}(q) < \text{nextR}(\text{parent}(q)))$ )
02 for ( $q_i \in \text{subtreeNodes}(q)$ ) // advance descendants
03   while ( $\text{nextL}(q_i) < \text{nextL}(\text{parent}(q_i))$ )
04     advance( $T_{q_i}$ )
05   PushMark( $T_{q_i}$ )
06   if ( $\text{isLeaf}(q)$ ) // solution in the streams' heads
      outputSolution()
07   else PathMPMJ(child( $q$ ))
08   advance( $T_q$ )
09 for ( $q_i \in \text{subtreeNodes}(q)$ ) // backtrack descendants
10   PopMark( $T_{q_i}$ )
```

PathMPMJ

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FIG. 8

```
Algorithm TwigStack(q)
    // Phase 1
01  while ¬end(q)
02      qact = getNext(q)
03      if (¬isRoot(qact))
04          cleanStack(parent(qact), next(qact))
05      if (isRoot(qact) V ¬empty(Sparent(qact)))
06          cleanStack(qact, next(qact))
07          moveStreamToStack(Tqact, pointer to
                                top(Sparent(qact)))
08          if (isLeaf(qact))
09              showSolutionWithBlocking(Sqact, 1)
10             pop(Sqact)
11         else advance(Tqact)
    // Phase 2
12 mergeAllPathSolutions()

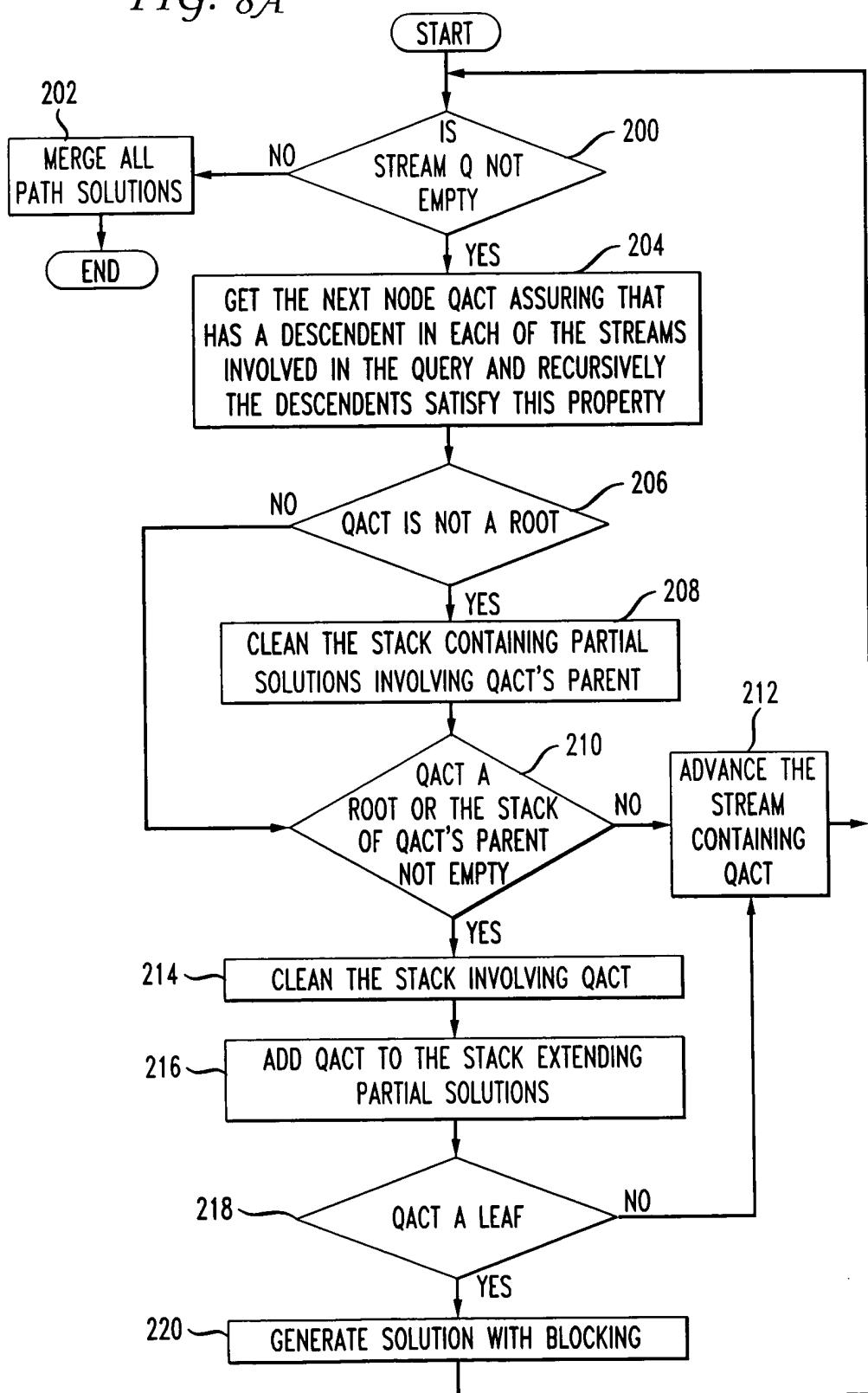
Function getNext(q)
01  if (isLeaf(q) return q
02  for qi in children(q)
03      ni = getNext(qi)
04      if (ni ≠ q) return ni
05  nmin = minargni nextL(Tni)
06  nmax = maxargni nextL(Tni)
07  while (nextR(Tq) < nextL(Tnmax))
08      advance(Tq)
09  if (nextL(Tq) < nextL(Tnmin)) return q
10  else return nmin

Procedure cleanStack(S, actL)
01  while (¬empty(S) ∧ (topR(S) < actL))
02      pop(S)
```

TwigStack

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FIG. 8A



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FIG. 9

```

Algorithm TwigStackXB(q)
01  while ¬end(q)
02    qact = getNext(q)
(03)  if (isPlainValue(Tqact))
04    if (¬isRoot(qact))
05      cleanStack(parent(qact), next(qact))
06    if (isRoot(qact) V ¬empty(Sparent(qact)))
07      cleanStack(qact, next(qact))
08      moveStreamToStack(Tqact, pointer to
                           top(Sparent(qact)))
09    if (isLeaf(qact))
10      showSolutionsWithBlocking(Sqact, 1)
11      pop(Sqact)
12    else advance(Tqact)
(13)  else if (¬isRoot(qact) ∧ empty(Sparent(qact)) ∧
           nextL(Tparent(qact)) > nextR(Tqact))
(14)  advance(Tqact) // Not part of a solution
(15)  else // Might have a child in some solution
(16)  drillDown(Tqact)
      // Phase 2
17  mergeAllPathSolutions()

```

```

Function getNext(q)
01  if (isLeaf(q)) return q
02  for qi in children(q)
03    ni = getNext(qi)
(04)  if (qi ≠ ni V ¬isPlainValue(Tni)) return ni
05  nmin = minargni nextL(Tni)
06  nmax = maxargni nextL(Tni)
07  while (nextR(Tq) < nextL(Tnmax))
08    advance(Tq)
09  if (nextL(Tq) < nextL(Tnmin)) return q
10  else return nmin

```

```

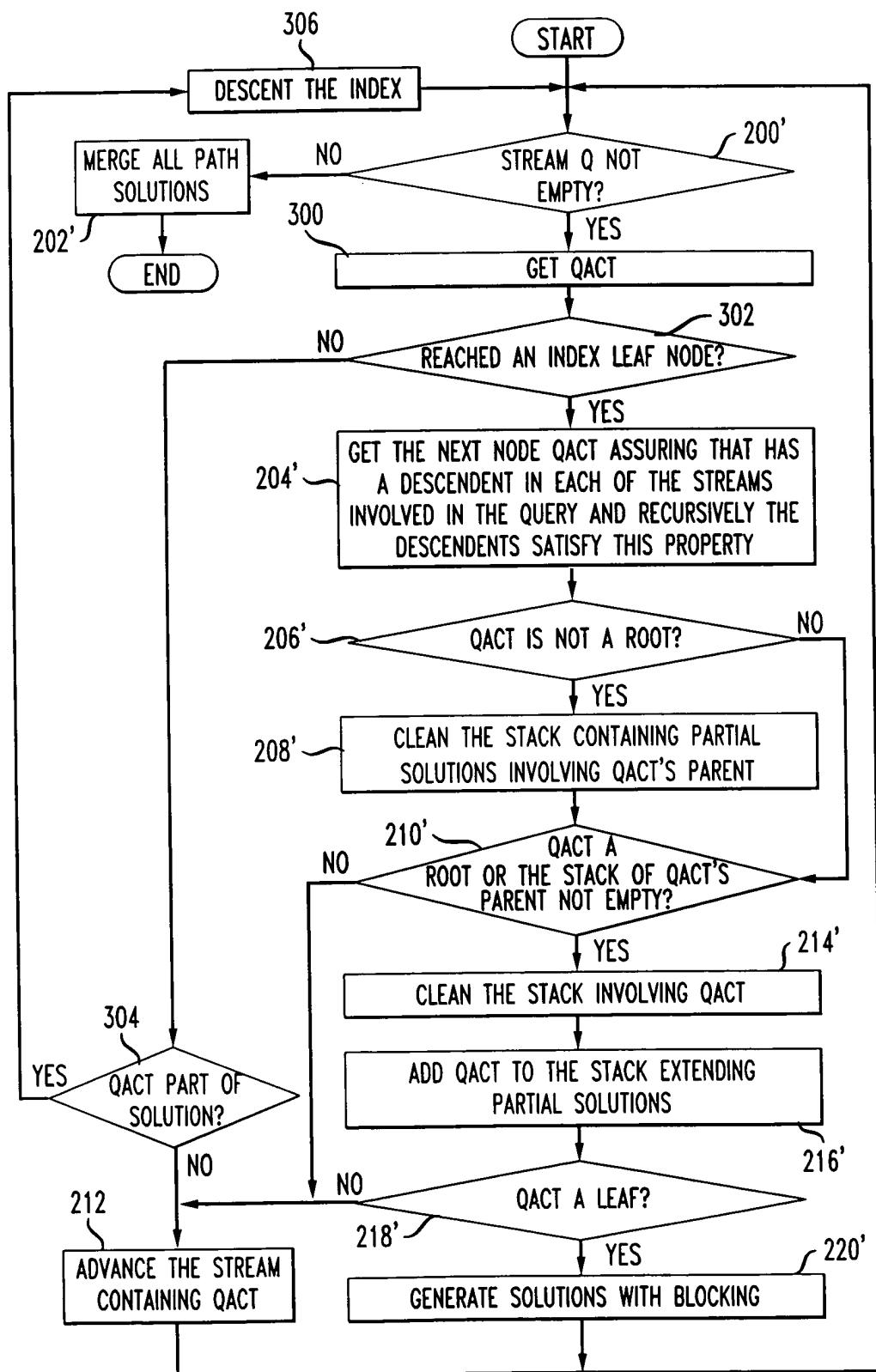
Procedure cleanStack(S, actL)
01  while (¬empty(S) ∧ (topR(S) < actL))
02    pop(S)

```

TwigStack

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FIG. 9A



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FIG. 10

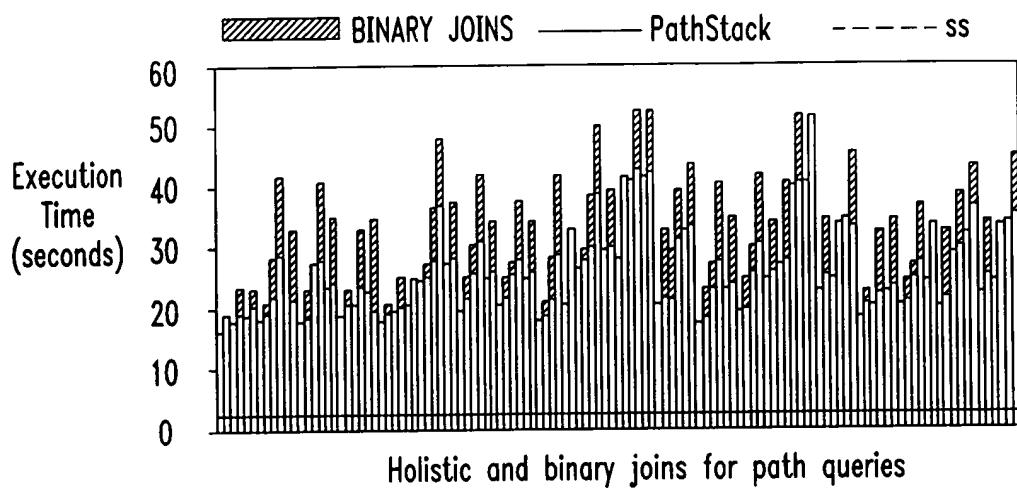
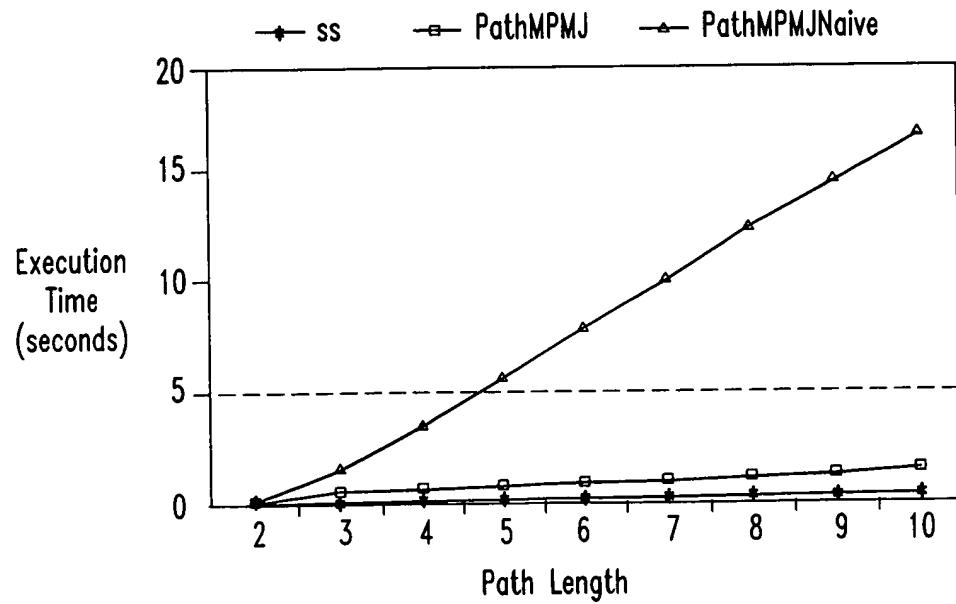


FIG. 11



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FIG. 12A

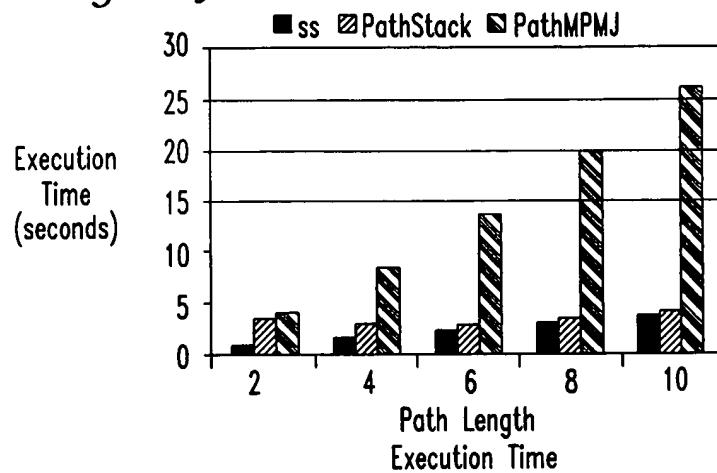
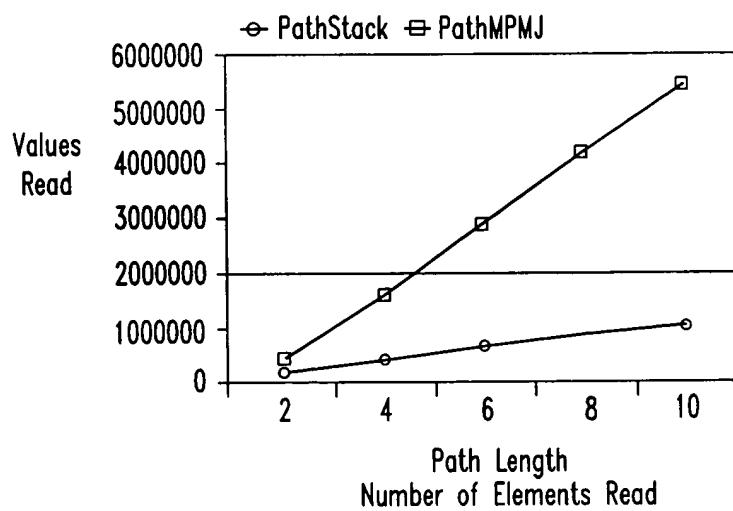


FIG. 12B



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FIG. 13A

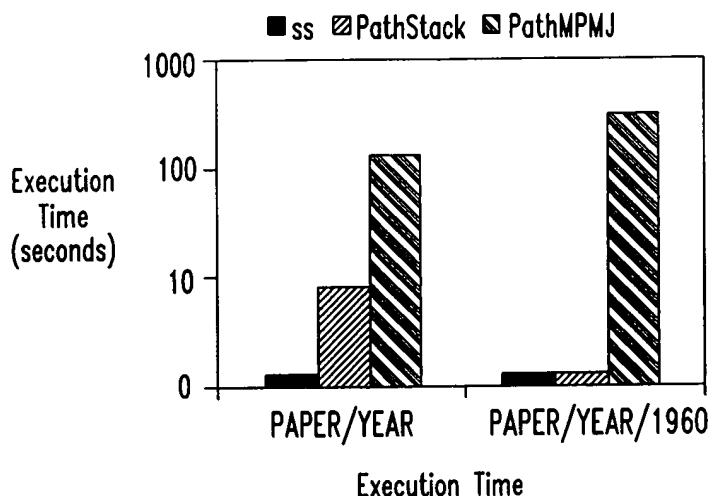
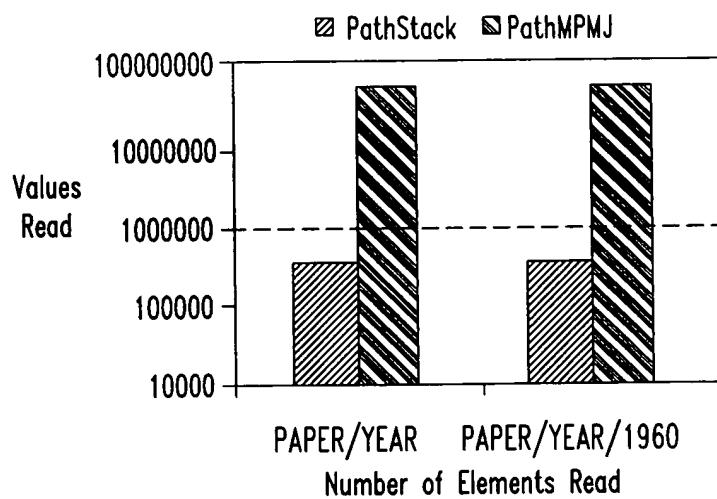
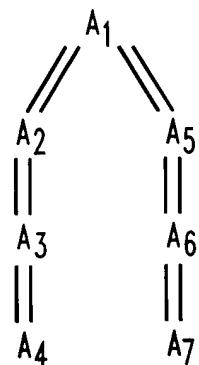
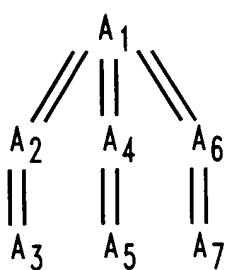
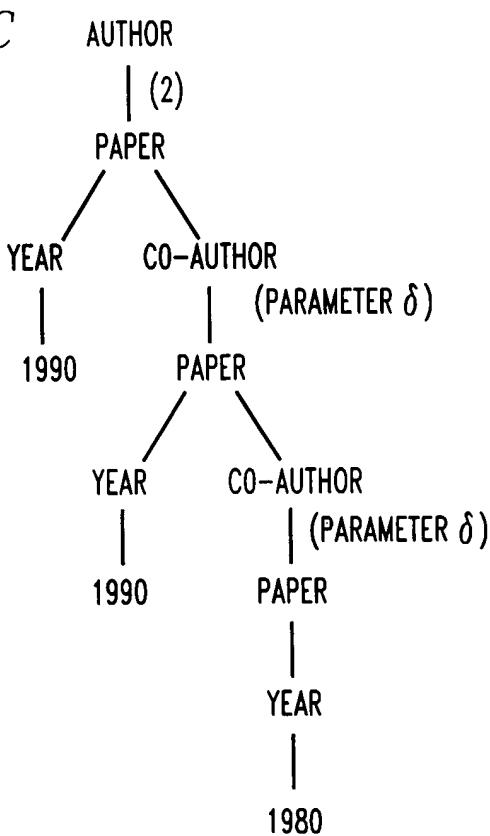


FIG. 13B



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FIG. 14A*FIG. 14B**FIG. 14C*

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FIG. 15A

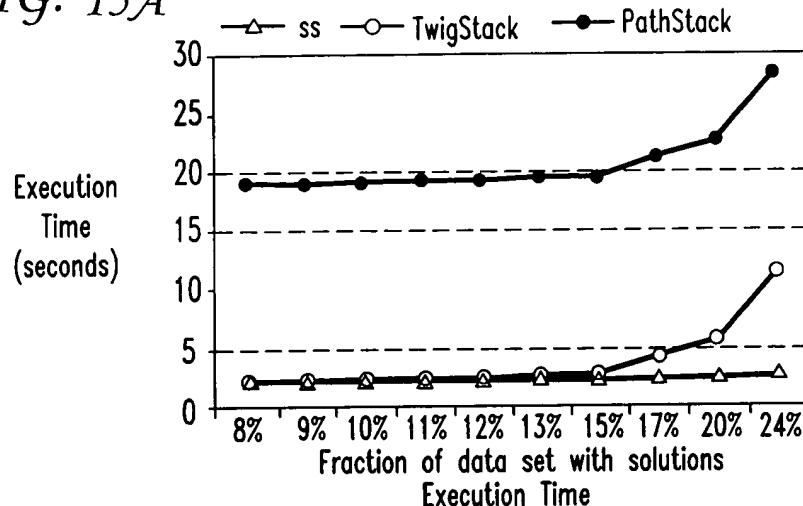


FIG. 15B

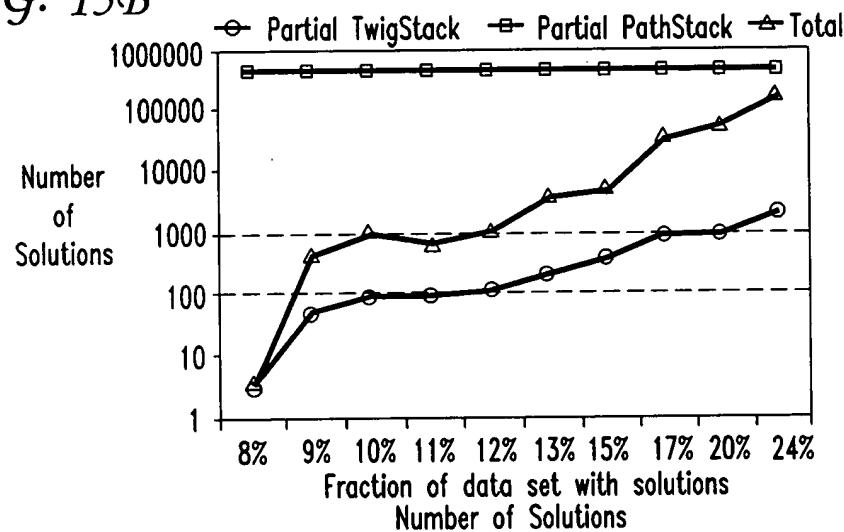
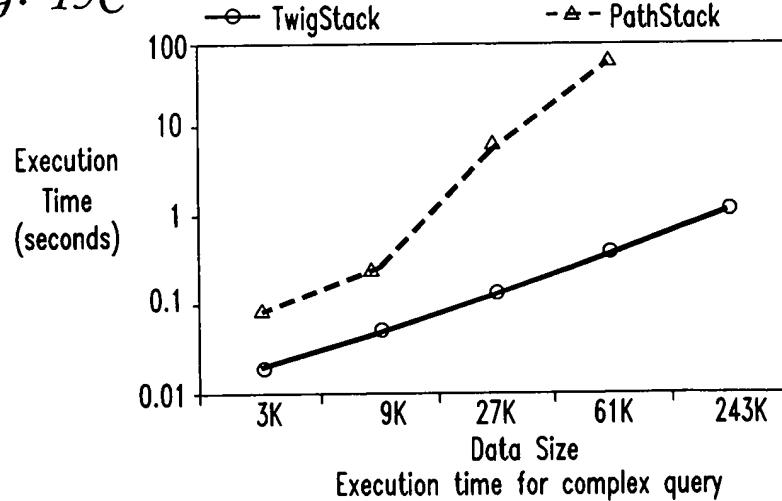


FIG. 15C



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FIG. 16A

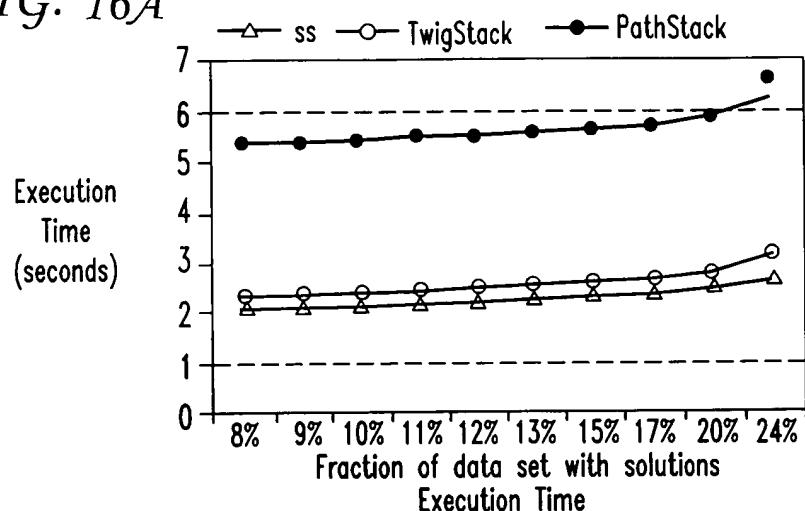


FIG. 16B

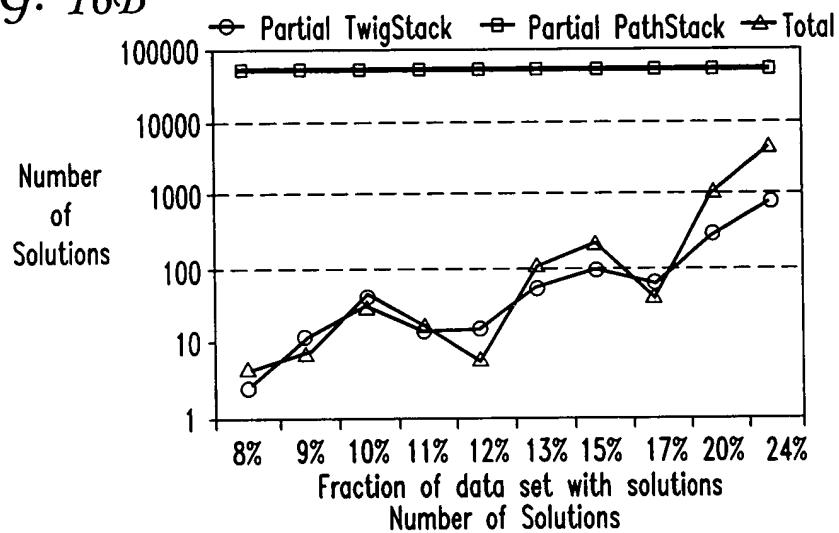
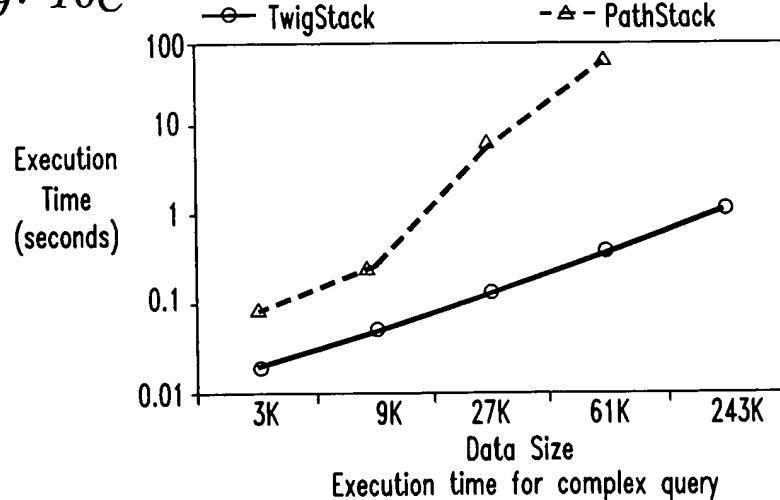
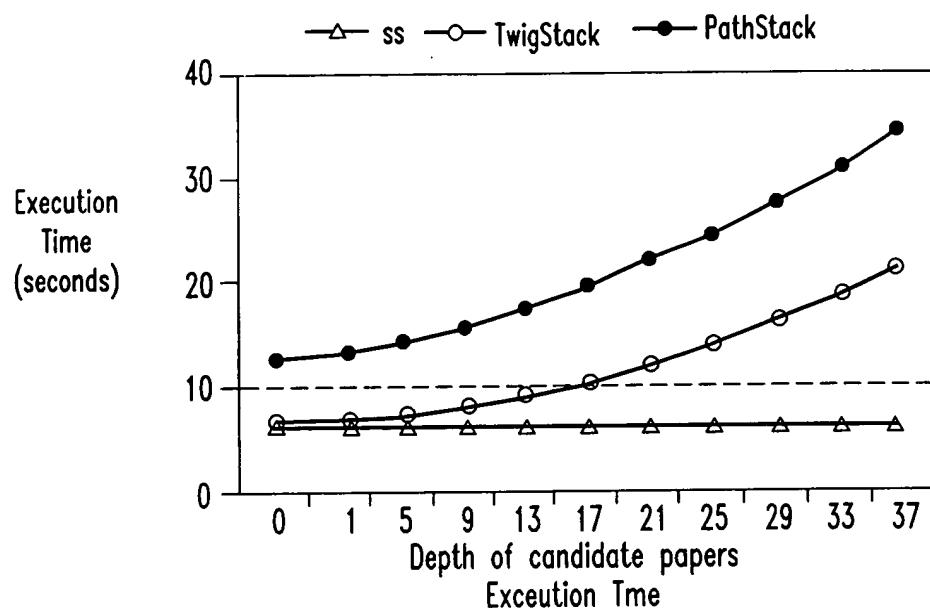
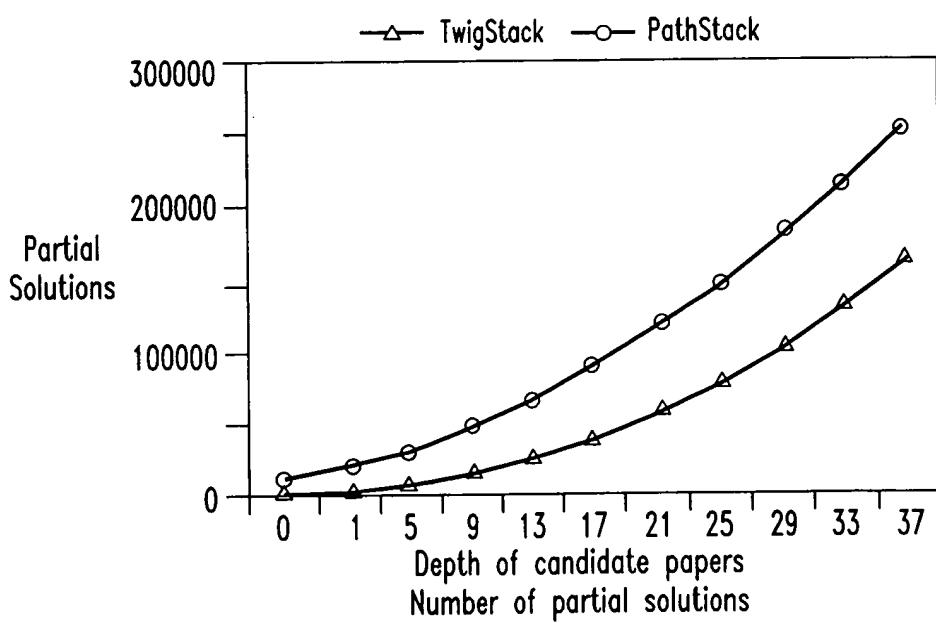


FIG. 16C



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FIG. 17A*FIG. 17B*

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FIG. 18A

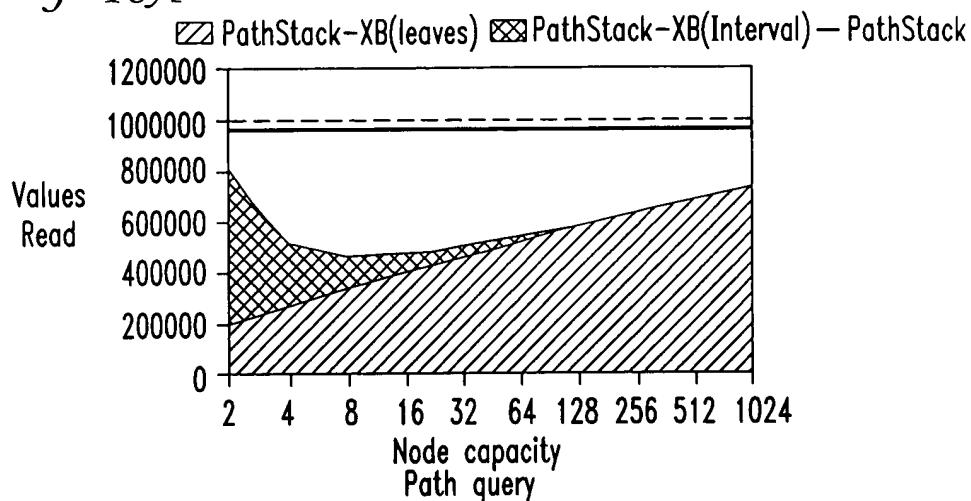


FIG. 18B

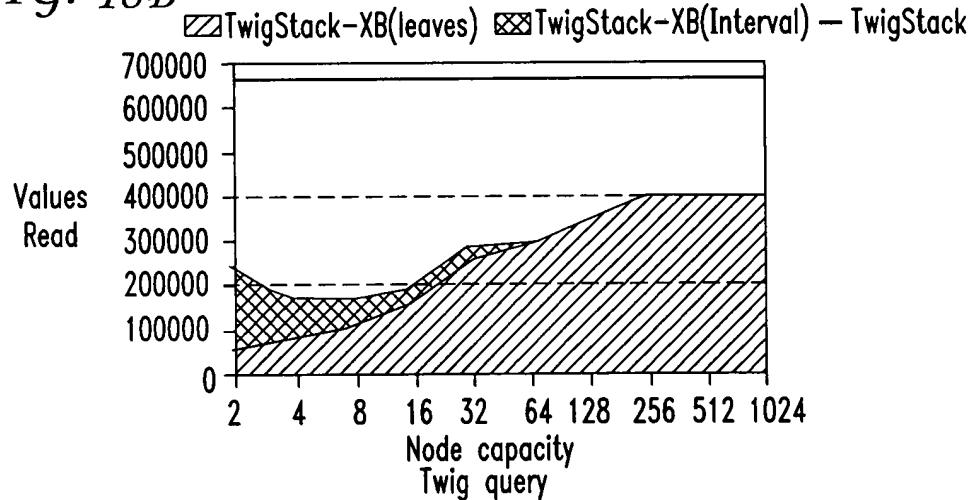


FIG. 18C

